Effect on Concrete by Partial Replacement of Cement by Colloidal Nano Alumina and Fly Ash

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Abstract— *Nanotechnology is a optimistic field in terms of environmental improvements including energy savings and reduced reliability on non-renewable resources, as well as reduced waste, toxicity and carbon emissions. Alumina component reacts with calcium hydroxide produced from the hydration of calcium silicates. The rate of the pozzolanic reaction is proportional to the amount of surface area available for reaction. Therefore, it is possible to add nano- Alumina of a high purity and a high Blaine fineness value in order to improve the characteristics of cement mortars*

The Aim of this project is to devlope the nano concrete and to study the effects of nano alumina on the properties of concrete. In this investigation the cement is replaced by 10% Fly-ash and Alumina nanoparticles of different proportion i.e 0.5%, 1%, 1.5%, 2.0%, 2.5% & 3% in M40 grade of concrete. It is observed that workability decreased with replacement of cement. The compressive strength of nano concrete casted by partially replacement of 10% fly ash & 2% & 2.5% colloidal nano alumina , increased over conventional concrete about 18.03%, 14.28% for 3 days and 12.7%, 11.27% for 7 days and 4.17% , 2.07% for 28 days. The Split Tensile strength of this concrete increases with 5.73% and 9.16% respectively over conventional concrete for the replacement 1.5% and 2%. Flexural strength of this concrete increases with 13.05% and 26.65% over conventional concrete for the replacement 2% and 2.5%.

Keywords— Cement, Concrete, Fly Ash, Nano Alumina, Strength.

I. INTRODUCTION

Concrete is the most widely used construction material in the world. Mixture of fine powdered cement, aggregates of various sizes and water with inherent physical and chemical properties produces Concrete which is a highly heterogeneous. To increase the strength of concrete adhesion between aggregate surface and cement paste and also strength of these materials plays important role. High strength concrete can be produced because of the advancement in concrete technology and availability of various nano material and mineral. Now a days nano technology has great importance because of the use of nano scale particles results in significantly improved properties. The mechanical behavior of concrete materials depends to a great extent on structural elements and phenomena that are effective on a micro- and Nano scale.

By incorporating nano-materials into matrix to improve mechanical properties emerged as a promising research field of nano-composite Compared with the case of dense structure matrix such as polymer, the situation is quite different in the area of cement matrix composites, because cement-matrix has relative loose structure. There are nanosized air voids present in between cement and aggregate which may have significant effect on the nanocomposite's mechanical properties.

1.1 Nano technology

The word “Nano” was derived from the Greek word dwarf which indicates a billionth part. Nanometer means billionth of a meter. Nanotechnology is the use of very small particles in the scale of 1-100 nanometers. A nanometer is 1/1000 of a micron, or 1 billionth of a meter which is about three atoms set side by side. The grain size is of the order of 10^{-9}m. It has extremely large specific surface area. It has favorable structural and nonstructural properties. The precise size at which the properties of materials are manifested varies between materials, but is usually in the order of 100 nm or less.

More dense and compact concrete microstructure can be produced by using nano material, it fills voids, accelerate the hydration reaction, create better bond between cement paste and aggregates, as they are having high surface area. Many investigations are carried out in addition of nano-silica, nano clay, nano titanium and carbon nano tubes to improve properties of cement mortar or concrete, but addition of nano alumina increases hydraulic activity of materials which are slowly reactive & improve strength of concrete at early ages. Compared to the other form of materials used in construction concrete is one of the most common and predominantly used constructional

materials. The properties of concrete can be changed by many ways, incorporation of nano particles is one of the best way. Nano particles in terms of nano silica, nano clays, nano titanium Oxide (tio_2), Nano Iron (Fe_2O_3), Nano alumina (Al_2O_3), Cuo, zno_2 and zro_2. Nanomaterials in concrete will improve the pore structure of concrete, speed up the C-S-H gel formation and improve the concrete mechanical and durability properties. More specifically fly ash improves durability and strength of the concrete to the maximum extent.

The reason for using Al_2O_3 as a partial replacement by cement is the C-A-H (limealumina- calcium sulfate) gel formation in concrete. The major constituent of a pozzolan is the alumina that can be amorphous or glassy. This component reacts with calcium hydroxide produced from the hydration of calcium aluminates. The rate of the pozzolanic reaction is proportional to the amount of surface area available for reaction. Therefore, it is possible to add nano- Al_2O_3 of a high purity (99.9%) and a high Blaine fineness value (60 m2/g) in order to improve the characteristics of cement mortars.

II. LITERATURE REVIEW

Pawel Niewiadomski *et.al* (2015), Studied rheological properties, microstructure and compressive strength. The obtained results showed that SiO_2 and Al_2O_3 additions worsened the workability while the compressive strength was increased in the case of SiO_2 addition.

Ahmed A. Amer *et.al* (2014), studied Thermal durability of OPC pastes admixed with nano iron oxide. This work is to investigate the influence of NF on the fire resistance of OPC pastes.

Parang Sabdono et.al(2014), had studied the effect of nano-cement content to the compressive strength of mortar. It was found that the substitution of nano-cement particles increases the compr ession strength of mortar at the age of 28 days.

A.H. Shekaria, M.S. Razzaghib(2011), Investigate the influence of Nano particles on mechanical properties through the compressive and indirect tensile strength and durability through chloride penetration test and concrete permeability. Nano materials in improvement of mechanical properties of high performance concrete.

Mounir Ltifia *et.al* (2011), Investigate the properties of cement mortars with nano-SiO_2. The compressive strengths of different mortars increase with the increasing of the amount of nano SiO_2.

III. MATERIALS USED

1. Cement:

Cement is a fine, grey powder. It is mixed with water and materials such as sand, gravel, and crushed stone to make concrete. The cement and water form a paste that binds the other materials together as the concrete hardens. Here an ordinary Portland cement (OPC 53 grade) was used.

Table 1:- Physical properties of Cement

Sr No.	Description of Test	Results	As per IS: 12269-1987
1.	Fineness of cement (residue on IS sieve No. 9)	3 %	> 10%
2.	Specific gravity	3.15	3.15
3.	Standard consistency of cement	31 %	33 %
4.	Setting time of cement a) Initial setting time b) Final setting time	112 minute 238 minute	> 30 < 600
5.	Soundness test of cement (with Le-Chatelier‟s mould)	1.8 mm	10 mm

2. Fly Ash

Fly ash used in this study is low calcium class F processed fly ash from Dirk India pvt Ltd. Under the name of the product POZZOCRETE 60.

Table 2:- Chemical composition of fly ash.

Chemical Comp-osition	*SiO_2*	*Al_2O_3*	*Fe_2O_3*	*MgO*	*SO_3*	*Na_2O*	*CaO*	*LOI*
%	*57.3*	*27.13*	*8.06*	*2.13*	*1.06*	*0.73*	*0.03*	*1.06*

3. Fine Aggregate

Natural river sand passing through 4.75 mm was used as fine aggregate and was tested following Is: 383-1970. The sand conformed to zone II.

Table 3:- Physical Properties of Fine Aggregate

Sr. No.	Property	Results
1	Particle shape and size	Round, Below 4.75 mm
2	Fineness Modulus	3.12
3	Silt Content	3.5 %
4	Specific Gravity	2.60
5	Surface Moisture	2 %

4. Coarse Aggregate

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The aggregates were selected based on the limitation of IS 881 and 882 and the aggregate was 12.5 mm and 20 mm crushed granite.

5. Colloidal Nano alumina:

Used nano Alumina that fills the pore spaces of concrete. Particle size of nano alumina is 5 nM to 8 Nm

Fig.1: Colloidal Nano Alumina

Table 4:- Properties of colloidal nano-alumina

Parameter	Active components	Particle size	Specific Gravity	Ph
Value	10%	5-8 nm	1.0-1.1	6.0

6.Water

Potable tap water available in lab was used for casting and curing of concrete.

7. Admixure

Commercially available super plasticizer is used.

IV. EXPERIMENTATION AND TESTS

Mix Proportioning:-

The mix design is done according to the IS design method M 40 Grade concrete was used with 0.38 W/ C ratio. It is used to produce concrete with replacement of cement by 0.5%, 1%, 1.5%, 2%, 2.5%, 3% of Nano alumina and 10% of Fly Ash. The compressive test on hardened concrete were performed on Universal testing machine. Concrete cubes of size 150×150×150mm were cast. Total 72 cubes were cast for \ determination of compressive strength. Compressive strength of concrete cubes was tested at 3 days, 7 days and 28 days. Total 24 cubes were cast for pull out and test was taken at 28 days. Total 24 concrete cylinders were cast for determination of split tensile strength and test was taken at 28 days. Total 24 beam specimens were cast to determine flexural strength and the beam specimens were tested at 28 days.

Mixing

Measured quantities of coarse aggregate and fine aggregate were spaced out over an impervious concrete floor. The dry OPC were spread out on the aggregate and mixed thoroughly in dry state turning the mixture over and over until the uniformity of color was achieved. Water was measured exactly by way and it was thoroughly mixed to obtain homogenous concrete. The mixing shall be done for 10 to 15 minutes.

Placing and Compacting

The cube mould and cylinder moulds are cleaned and all care is taken to avoid irregular dimensions. The joints between the sections of mould were coated with oil and similar coating of mould was applied between the contact surfaces during filling. The mix was placed in 3 layers and the layer was contacted using table vibrator to obtain dense concrete.

Curing

The test specimen cubes and cylinders were stored in a place free from vibration in moist air at 90% relative humidity and at temperature of 27+/ for 24 ½ hours from the time of addition of water to dry ingredients. After 24 hours the specimens demoulded and immediately immersed in clean, fresh water tank for period of 3,7,28 days.

Testing

After the required curing (i.e. 28 days) the specimen are tested under the compression testing machine. The loads should be applied gradually at the rate of 14MPa per minute til the specimen fails. The testing shall be done on at least three specimens at each selected edge. if the strength of any specimen varies by 15 % of the average strength, the result should be rejected.

A} Compressive Strength Test:-

For the compression test, the cubes (150mm X 150mm X 150mm) are placed in machine in such a manner that the load is applied on the Forces perpendicular to the direction of cast. In Compression testing Machine, the top surface of machine is fixed and load is applied on the bottom surface of specimen. The rate of loading is gradual and failure (crushing) load is noted. Also the failure pattern is observed precisely. The test result is the average of at least three standard cured strength specimens made from the same concrete sample and tested at the same age. In most cases strength requirements for concrete are at an age of 28 days.

The average compressive stress for different mix are calculated as below:

Compressive strength (fc) = P/A

Where,

P = Load at failure in N

A = Surface area of cube in m

Fig.2: Mould of size 15cm x 15cm x15cm

B] Split Tensile Strength test

For determining split tensile strength, cylinder specimens of size 150mm in diameter & 300mm in length are placed

between the two plates of Compression Testing Machine. The load is applied at a uniform rate till the specimen failed by a fracture along vertical diameter. This method consists of a applying a diametric compressive force along the length of a cylindrical specimen. This loading induces tensile stresses on the plane containing the applied load. Tensile failure occurs rather than compressive failure. Plywood strips are used so that the load is applied uniformly along the length of the cylinder. The maximum load is divided by approximate geometrical factors to obtain the splitting tensile strength. A diametrical compressive load is then applied along the length of the cylinder until it fails because PCC is much weaker in tension than compression, the cylinder will typically fail due to horizontal tension and not vertical compression.

The average tensile stress for different mix is entered in the table which is shown in next chapter. Calculate the splitting tensile strength as given by equation.

Split Tensile Strength (T) = $2P/\pi lD$

Where,

T = Split tensile strength in N/mm²

P = Maximum load at failure in N.

L = length of the cylindrical specimen in mm.

D = diameter of cylindrical specimen in mm.

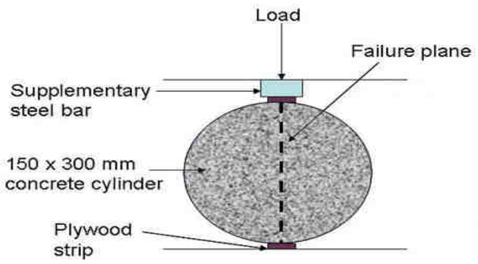


Fig.3: Split Tensile Strength test

C] Flexural strength test:

Concrete as we know is relatively strong in compression and weak in tension. In reinforced concrete members, little dependence is placed on the tensile strength of concrete since steel reinforcing bars are provided to resist all tensile forces. However, tensile stresses are likely to develop in concrete due to drying shrinkage, rusting of steel, temperature gradient and many other reasons. Therefore, knowledge of tensile strength of concrete is of importance. In the test comparison is made between Portland cement concrete (PCC) and Fly ash with nano alumina based concrete by taking the same size of beam 100 X 100 X 500 mm. Test specimen of both concrete are cured in the curing tank for 28 days and then left and tested at the age of 28 days. The flexural strength of the specimen is expressed in N/mm² is calculated as :

Flexural strength (F) = PL/bd^2

Where,

F - Flexural strength of concrete in N/mm²

P - Maximum load at failure in N

L - Length of the beam specimen in mm

b - Width of the beam specimen in mm

d - Thickness of the beam specimen in mm

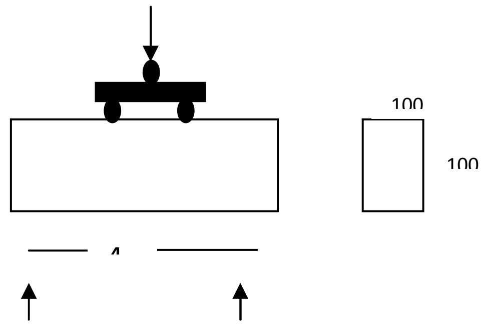


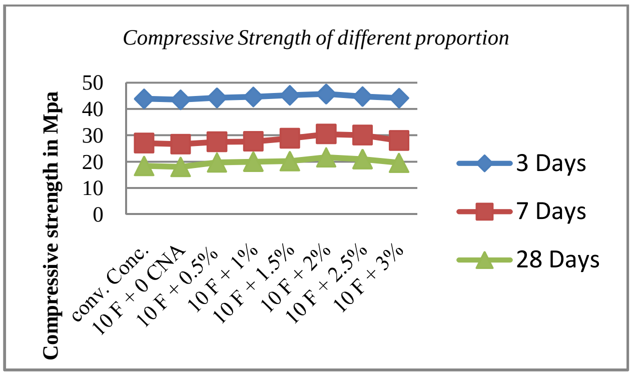
Fig.4: Two Point Loading Setup in Flexure Test.

V. RESULT AND DISCUSSION

a} Compressive strength test:-

Table 5:- Compressive strength of specimen

Sr. No.	**Concrete mix no.**	**Replacement in %**		**Compressive Strength in N/mm^2**		
		Fly ash	CNA	3 Days	7 Days	28 Days
1.	A1	0	0	18.41	27.07	43.90
2.	A2	10	0	18.04	26.66	43.54
3.	A3	10	0.5	19.77	27.56	44.32
4.	A4	10	1	20.06	27.70	44.64
5.	A5	10	1.5	20.23	28.89	45.21
6.	A6	10	2	21.73	30.51	45.73
7.	A7	10	2.5	21.04	30.12	44.81
8.	A8	19	3	19.58	28.02	44.17



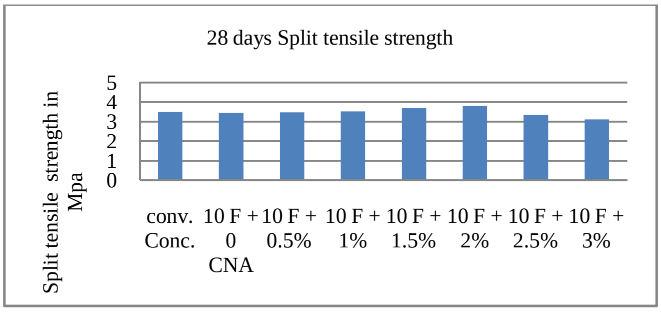
Graph 1 : 3, 7, & 28 Days Compressive Strength of different proportion

b] Split tensile Strength test:-

Table 6:- Split Tensile strength of specimen

Sr No	**Concrete mix no.**	**Replacement in %**		**Split tensile Strength at 28 days in N/mm^2**
		Fly	CNA	

		ash		
1.	A1	0	0	3.49
2.	A2	10	0	3.44
3.	A3	10	0.5	3.47
4.	A4	10	1	3.52
5.	A5	10	1.5	3.69
6.	A6	10	2	3.81
7.	A7	10	2.5	3.34
8.	A8	19	3	3.12

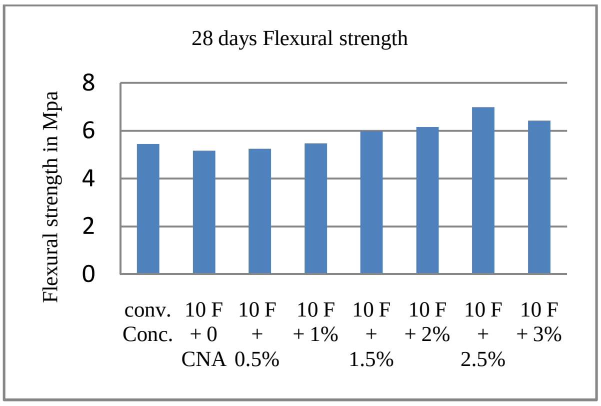


Graph 2:-28 Days Split tensile Strength of different proportion.

c] Flexural test:-

Table 7 :-Flexural strength of specimen

Sr No	Concrete mix no.	Replacement in %		Flexural Strength at 28 days in N/mm^2
		Fly ash	CNA	
1.	A1	0	0	5.44
2.	A2	10	0	5.16
3.	A3	10	0.5	5.25
4.	A4	10	1	5.47
5.	A5	10	1.5	5.98
6.	A6	10	2	6.15
7.	A7	10	2.5	6.89
8.	A8	19	3	6.42



Graph 3:-28 Days Flexural Strength of different proportion.

VI. CONCLUSION

On the basis of the result obtained during the experimental investigation, following conclusions were draw

1) Concrete made by using Nano alumina with fly ash, initially it gives the higher compressive strength for the replacement 2% and 2.5% after that it was to decrease for 3%.
2) The compressive strength was found 18.03%, 14.28% higher than that of conventional concrete when cement is replaced by 10% Fly ash and 2% and 2.5% Nano alumina respectively for the age of concrete 3 days.
3) The compressive strength was found 12.7%, 11.27% higher than that of conventional concrete when the cement is replaced by10% Fly ash and 2% and 2.5% Nano alumina respectively for the age of concrete 7 days.
4) Compressive strength of Nanoconcrete was higher by 4.17% and 2.07% than that of conventional concrete for the replacement of 2% and 2.5% at the age of concrete 28 days.
5) Split Tensile strength of Nano concrete was higher by 5.73% and 9.16% than that of conventional concrete for the replacement of 1.5% and 2% at the age of concrete 28 days.
6) Flexural strength of Nano concrete was higher by 13.05% and 26.65% than that of conventional concrete for the replacement of 2% and 2.5 % at the age of concrete 28 days.

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REFERENCES

[1] Pawel Niewiadomski, Andrzej Cwirzen, Jerzy Hola (2015) "*The influence of an additive in the form of selected nanoparticles on the physical and mechanical characteristics of self-compacting concrete*". XXIV R-S-P seminar, Theoretical Foundation of Civil Engineering (24RSP) (tfoce 2015). Procedia Engineering 111 (2015) 601 – 606

[2] N. Venkat Rao, M. Rajasekhar, K. Vijayalakshmi, M. Vamshykrishna (2015) ''*The Future of Civil Engineering with the Influence and Impact of Nanotechnology on Properties of Materials*''. Procedia Materials Science 10 (2015) 111 – 115

[3] Ahmed A. Amer, Tarek M. El-Sokkary , Nagwa I. Abdullah (2014) ‘‘*Thermal durability of OPC pastes admixed with nano iron oxide*’’. Received 15 April 2014; revised 23 April 2014; accepted 27 April 2014, HBRC Journal (2015) 11, 299–305

[4] Parang Sabdono, Frisky Sustiawan, Dion Aji Fadlillah (2014) ‘‘*The effect of nano-cement content to the compressive strength of mortar*’’. Procedia Engineering 95 (2014) 386 – 395

[5] Sri Tudjono Purwantob, Kartika Trisna Apsari (2014) ‘‘*The effect of adding nano fly ash and nano lime to compressive strength of mortar*’’. Procedia Engineering 95 (2014) 426 – 432